Tropospheric Scintillation and its Impact on Earth-Space Satellite Communication in Nigeria

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***Abstract*—The study investigates the impact of tropospheric scintillation on fixed satellite communication link on earth-space path for frequencies between 10 and 50 GHz for 37 stations in Nigeria. Elevation angles of 5º, 55º which are typical look angles for links over the Atlantic Ocean region and Indian Ocean region, look angles to the Nigeria Communication Satellite was also considered. Meteorological climatic data retrieve from satellite such as; profiles of temperature, pressure, and relative humidity, were validated with the available ground data in Nigeria. These data were reprocessed to derive radio propagation input parameters, such as; water vapour density integrated water vapour content and radio refractivity. Secondly, the International Telecommunication Union Propagation model (ITU-P 618, 2009) was used to estimate tropospheric scintillation for time unavailability between 0.01 to 10% in an average year. The result shows that scintillation fade depth is between 4.0 to 19.0 dB and 0.2 to 1.3 dB at 5º and 55º elevation angles respectively. For links to NigComsat scintillation fade depth is between 0.05 to 1.26 dB for all the 37-locations. The results will help in designing, planning and quick integration and expansion of satellite telecommunication services in the six regions of Nigeria.**

I. Introduction

Tropospheric scintillation is caused by small-scale refractive index inhomogeneities induced by tropospheric turbulence along the propagation path especially in the presence of clouds, such as cumulus and cumulonimbus clouds mostly around noon. It results in rapid fluctuations of received signal amplitude and phase which affect Earth-space radio links. Above 10 GHz, tropospheric scintillation intensity has been shown to increase with increasing carrier frequency and with decreasing elevation angle and antenna size [1]. Scintillation fades can also have a major impact on the performances of high frequencies, low fade margin communication systems, for which the long-term availability is sometimes predominantly governed by scintillation effects rather than by rain [2-5]. In addition, the dynamics of scintillation may interfere with tracking systems or fade mitigation techniques.

References [6-7] revealed scintillation models support the observation that scintillation is more pronounced under high-temperature and high-humidity conditions such as in tropical regions or temperate regions in summer. At low elevation angles, the fading caused by scintillation has been discovered by measurements to exceed attenuation caused by rain, particularly at percentages above 1% unavailability (or 87.5 hours signal outage) in an average year [8]. In particular, scintillation generated on propagation paths at low elevation angles often produces considerable signal fading in excess of 10 dB [9].

II. DATA ACQUISITION

The input parameters obtained from Atmospheric Infrared Sounder Satellite (AIRS) was used for the study of tropospheric scintillation loss on earth-space path at the 37 stations in Nigeria. The daily surface temperatures, pressure, and relative humidity, have been used to derive the monthly and annual values of wet term of radio refractivity (Nwet), which is the major input parameter, needed for the computation of scintillation fade depth. Figure 1 show the map 37-stations and the six-regions in Nigeria.

The wet term of radio refractivity Nwet (N-unit) is given by [10]:

$$N_{wet} = 3.732 \times 10^5 \frac{e}{T^2} \tag{1}$$

where T is absolute temperature (K) and water vapour pressure e, is given by:

$$e = \frac{He_s}{100} \tag{2}$$

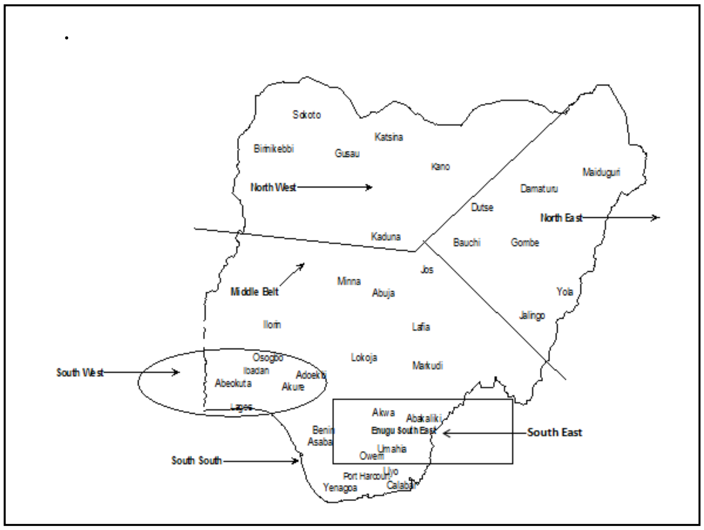
$$e_s = a \exp\left(\frac{bt}{t+c}\right) \tag{3}$$

where: H is relative humidity in percent, t is temperature in degrees C, es is saturation vapour pressure in hectoPascals (hPa) at the temperature t and coefficients a, b, c, as given by:

for water	for ice
a = 6.1121	a = 6.1115
b = 17.502	b = 22.452
c = 240.97	c = 272.55

are valid for water between –20° to +50°C with accuracy of ± 0.2% , and ice between –50º to 0ºC with an accuracy of ±0.20%.

Fig. 1. Map of Nigeria with the 37 stations and six regions



III. RESULTS AND DISCUSSION

The frequency characteristics of tropospheric scintillation fade depth along earth-space paths at the two elevation angles of 5º and 55º for 10 to 50 GHz at the 37 stations for 0.01% unavailability was studied. The results show that scintillation fade depth increases with increasing frequency and increases with decreasing elevation angle. At 5º elevations, scintillation fade depth is between 4.04 dB in the NorthWest (NW) to 19.08 dB in the SouthSouth (SS) regions. The results suggest that tropospheric scintillation is very high at low elevation angles and is comparable to rain attenuation. But at 55º elevation angle, scintillation fade depth is very low, ranges between 0.27 dB in the NW to 1.29 dB in the SS regions. At both elevation angles, the results show that scintillation fade depth is most severe in Calabar (SS) followed, in descending order, by Ikeja in the SouthWest (SW), Abakaliki in the SouthEast (SE), Abuja in the MiddleBelt (MB), Dutse in the NorthEast (NE) and Kastina NorthWest (NW) regions.

Also, scintillation fade depth at 5º elevations for Ku-band is between 4.27 to 9.09 dB, at Ka-band is between 6.05 to 14.17 dB, at V-band is between 9.06 to 16.75 dB for uplink and downlink frequencies at the 37 stations. At 55º elevation scintillation fade depth at Ku-band, is between 0.29 to 0.62 dB, at Ka-band is between 0.41 to 0.96 dB, at V-band is between 0.61 to 1.28 dB for uplink and downlink frequencies at the 37 stations. These results suggest that at very low elevation angles for V-band uplink, 99.99% availability may not be practicable in all the 37 stations, because scintillation fade depth is between 10.32 to 19.07 dB. Most clear sky conditions are designed with a fade margin of 6 to 7 dB. But at 55º elevations 99.99% availability is possible at all the 37 stations in all the frequency bands considered. Therefore, the results revealed that tropospheric scintillation intensity is very high at low elevation angles and antenna size.

IV. CONCLUSION

The impact of tropospheric scintillation on fixed satellite communication link on earth-space path for frequencies between 10 and 50 GHz at Ku, Ka and V bands for 37 locations in Nigeria had been investigated. Based on local meteorological climatic data retrieve from satellites such as (AIRS) and were validated with the available ground data in Nigeria. The International Telecommunication Union Radiowave Propagation model (ITU-RP 618, 2009) was used in the study to estimate attenuation due to tropospheric scintillation for 0.01 to 10% unavailability in average year. The result shows that scintillation fade depth is between 4.0 to 19.0 dB and 0.2 to 1.3 dB at 5º and 55º elevation angles respectively. Hence, the results suggest that tropospheric scintillation is very high at low elevation angles and is comparable to rain attenuation.

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